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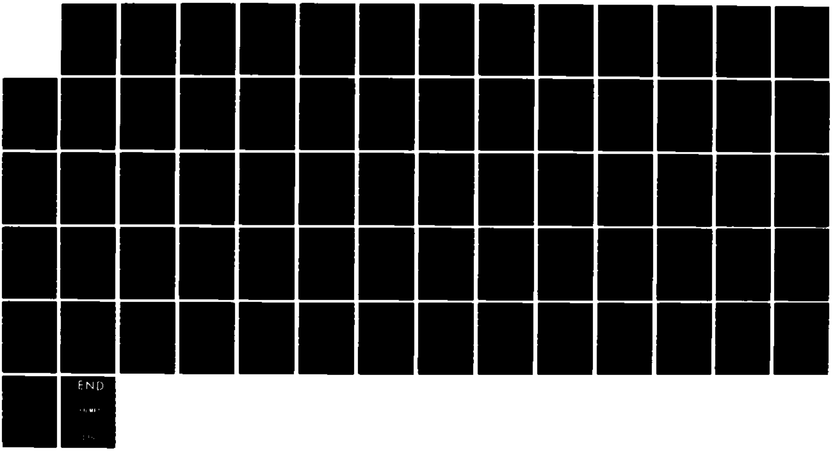

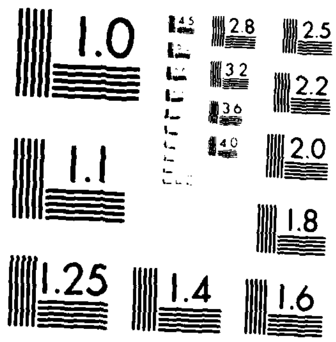

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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

THE OPTIMAL LOCATION

OF

COAST GUARD RECRUITING OFFICES

by

Timothy W. Rolston

September 1984

Thesis Advisor: Dan C. Boger

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The Optimal Location of Coast Guard Recruiting Offices

by

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Submitted in partial fulfillment of the requirements for the degree of

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The optimal location of Coast Guard Recruiting Offices and their recruiter allocation is investigated. Since quantity of recruits is not a problem with the Coast Guard, a reward model is developed to rate the quality potential of a recruiting area. This multiplicative model assumes that Navy recruiting performance can be used to predict Coast Guard recruiting potential. Integer dynamic programming is applied to determine the optimal allocation of recruiters using the reward model. A non-integer dynamic programming algorithm is also presented as a decision aid that can be used for recruiter allocation, quota assignment, boundary definition, recruiter performance evaluation, and recruiter time allocation. Paucity and possible errors in the Coast Guard data precluded strong conclusions about the reward model and subsequent results.

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I. BACKGROUND

A. RECRUITING IN THE ARMED FORCES

Prior to 1973 there was relatively little effort expended on recruiting for the Armed Forces. If there was a monthly or annual enlistment quota shortfall the remaining quota goals would be filled by draftees. This made the recruiting process quite easy and both quality and quantity goals were obtained. As a result there was little incentive to improve recruiting methods and only a few studies were conducted to advance these mediocre practices.

In 1973 when Congress abolished the draft, all of the major services (Army, Navy, Air Force, and Marines) were forced into a position which required aggressive recruiting to obtain the needed enlistees. Thus the first major recruiting studies centered around the effects of and issues related to the all-volunteer military system. As early as 1970, the Report of the President's Commission on an All-Volunteer Armed Force [Ref. 1] foresaw the need for improved recruiting methods under an all-volunteer system.

During the past decade numerous recruiting studies ranging from behavioral science research to intricate econometric modeling have been conducted. These studies, along with increased emphasis on threshold enlistment standards, have resulted in very sophisticated recruiting methodologies. The models developed have identified two basic groups of factors that influence recruiting. The environmental-demographic factors include such things as unemployment rates, civilian pay, qualified military available (17 to 21 year olds), and propensity to enlist, whereas the recruiting system factors include recruiting objectives, advertising, recruiting policy, entry programs available, etc.

One conclusion of these studies is that military recruiting is a highly dynamic process and therefore must be under constant analysis to remain effective. In recent years when unemployment was high all of the services enjoyed a good recruiting period. However, each of the services continues to research better methods since a poor economy is a temporary state. Presently two factors affecting recruiting are declining unemployment and declining target population (end of the baby boom). These changing circumstances make it necessary to continue forecasting and modifying recruiting techniques.

B. RECRUITING IN THE COAST GUARD

In recent years the Coast Guard has also developed a need for improved and more aggressive recruiting techniques. Prior to 1975 the Coast Guard enjoyed 'easy picking' compared to the other services since there was a high demand for the Coast Guard and relatively few positions available. This resulted in a high percentage of good quality recruits compared to the other services. Today, with more complex and sophisticated systems and equipment used by the Coast Guard, there is an even greater need for quality people in the Coast Guard. This greater need combined with increased competition for recruits from the other services requires that the Coast Guard become more aggressive in its recruiting activities.

The term 'quality' is often used loosely within recruiting circles, yet it is difficult to define explicitly, and even more difficult to measure and predict. Since the definition and measurement of a 'quality Coast Guard Recruit' is beyond the scope of this study, a 'quality' recruit will be defined in terms of two measures; mental aptitude and level of education.

The first measure, mental aptitude, is determined by the Armed Services Vocational Aptitude Battery (ASVAB). This test of mental aptitude is administered to all potential Coast Guard recruits prior to their enlistment. The test measures the level of skills for several items such as; arithmetic reasoning, numerical operations, paragraph comprehension, word knowledge, coding speed, general science, mathematics knowledge, electronics information, mechanical comprehension and automotive-shop information. This battery of tests is administered throughout the country for all the services with the results of the word knowledge, paragraph comprehension, arithmetic reasoning, and numerical operations sections being combined to form the Armed Forces Qualification Test (AFQT). The AFQT score is then divided into five "Mental Category" groups based on percentile as

TABLE I

AFQT Mental Categories by Percentile

AFQT Mental Category	Percentile
I	93 - 100
II	65 - 92
IIIA	50 - 64
IIIB	31 - 49
IV	10 - 30
V	1 - 9

shown in Table I . Categories I and II represent people that are above average in trainability; those in Category III are considered average, where IIIA represents individuals slightly above the median and IIIB represents those slightly below the median; those in Category IV are below

average; and Category V are well below average. As pointed out in the Profile of American Youth [Ref. 2], "The Services prefer enlistees in the higher AFQT categories because training time and associated costs are lower." These higher category people also qualify for a wider range of specialized training. Also, as noted by Mobley, Hand, Baker, and Meglino, [Ref. 3] persons in the higher mental categories tend to exhibit a better chance of completing recruit training over those of the lower mental categories. This is supported by recent Coast Guard data as shown in Table II .

TABLE II

Recruit Training Success by AFQT Category

	Recruit Training FY-82	
	Graduated	Discharged
Category I & II	97.9%	2.1%
Category IIIA	96.8%	3.2%
Category IIIB	93.1%	6.9%
Category IV & V	85.9%	14.1%

The second factor that is considered important relative to quality is the level of education. In a recent study by the Center for Naval Analysis [Ref. 4], it was concluded that:

> Finally, the military has found high school graduates to be better "quality" recruits than non-high school graduates (quality as measured by retention). High school graduation, in fact is the most important predictor of survival.

There have been numerous studies conducted which have the same conclusion and even Coast Guard data from fiscal year 1982 supports this conclusion as shown in Table III .

TABLE III
HSG vs. Non-HSG Survival

Recruit Training FY-82	Graduated	Discharged
HSG	82.5%	17.5%
Non-HSG	69.0%	31.0%
Overall Average	81.2%	18.8%

Although there may be many variables involved in determining a 'quality' recruit, substantial research has indicated that mental category and level of education attainment are valid predictors of future success in training [Ref. 5]. These measures are also readily available for each recruit and AFQT mental category is standardized nationally. For the purposes of the Coast Guard and this study, a 'good quality recruit' is defined as a high school graduate with a AFQT Category I or II.

With the definition of quality at hand it is now possible to evaluate the Coast Guard's recruiting position. Due to the relatively small number of enlistees brought into the Coast Guard, quantity was never a real concern and continues to be no concern at the present time. However, quality recruits and quality minority recruits are less abundant in the Coast Guard as compared to previous years. As can be seen in Figure 1.1, there has been a steady

decline in percentage of Mental Categories I and II in the Coast Guard from 1975 until 1981. In 1981 unemployment became very high and all of the services experienced good recruiting. As mentioned earlier this is only a temporary condition and tougher recruiting times lie ahead. This decrease in quality in the Coast Guard represents a threat to life, and property as equipment becomes more complex and training costs increase. To maintain a high quality and efficient service the Coast Guard must recruit high quality people.

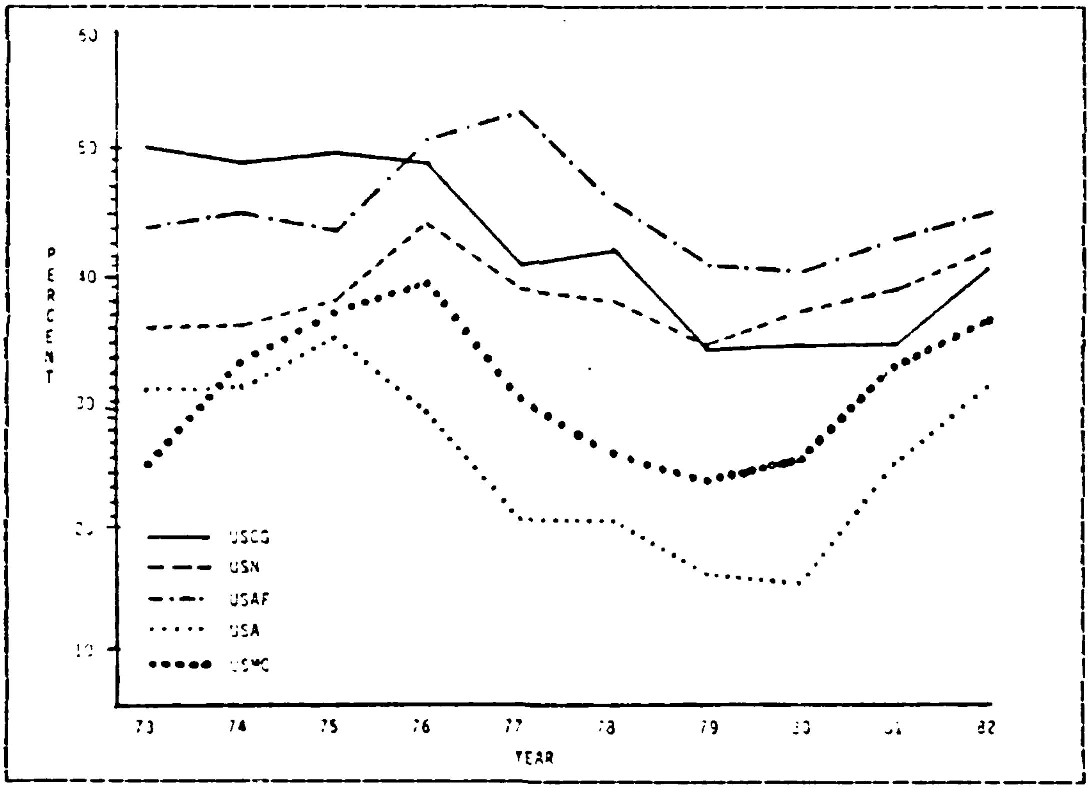

Figure 1.1 Percent of AFQT Category I and II Accessions.

The basic assumption behind many recent studies is that the upper mental category people (Cat I-IIIA) are 'supply

limited' [Ref. 5]. This means that the number of quality accessions is limited by the supply of these people rather than the military's demand for them. Since the four major services are all competing for these upper mental category people, the Coast Guard must also compete for these people. The Coast Guard can no longer sit back and rely on its reputation for attracting high quality recruits. The Coast Guard must improve its recruiting techniques to compete with the much more sophisticated methods used by the other services. In a time when budgets are tight the Coast Guard must make an effort to get more recruits for the dollar and this can be done by improving the present recruiting process.

C. POSSIBLE METHODS TO OBTAIN BETTER RECRUITS IN THE COAST GUARD

Initial investigation of the problem resulted in several possible solutions. For the Coast Guard's recruiting problem a combination of these solutions and those found in studies conducted by the other services on recruiting resulted in several viable alternatives for improvements. Assuming that improved quality in recruits and minority recruits (as measured by the mental category) is the goal of the Coast Guard the following list of solutions is obtained:

1. Train the recruiters better. With better training the recruiters may become more efficient and effective salesmen.
2. Advertise more.
3. Offer better and more flexible enlistments such as guaranteed schools or duty stations, and delayed entry programs.
4. Use more recruiters in more locations.

5. Relocate present recruiting offices into areas of greater potential. If upper mental category people with a propensity to enlist in the military are supply limited, the the Coast Guard should recruit in areas with the greatest supply.

While all of the above proposals may be good ideas for improvement, some may be expensive and difficult to implement. Because of Coast Guard Headquarters interest, this study will concentrate solely on the fifth proposal, the relocation of the recruiting offices into the 'optimal' locations. This presents a challenging problem with possibly the greatest payoffs relative to the effort and money expended.

D. OPTIMAL RECRUITING OFFICE LOCATION

There are presently sixty-five Coast Guard Recruiting Offices throughout the continental United States, Puerto Rico, and Hawaii. These offices have one to eight recruiters assigned to them for a total of 242 recruiters. Each office is responsible for recruiting within a geographical area assigned by Coast Guard Headquarters. This geographical area is usually defined by a list of counties that make up the territory of responsibility. Most of the recruiting is done within a sixty mile radius of the office. There is no incentive to recruit people of quality greater than a minimum standard, hence a recruiter can reach the quota without canvassing the complete territory. The data for Coast Guard enlistments in FY83 show that most of the applicants and eventual accessions come from only a few of the counties assigned to a given office. This suggests that while the Coast Guard may assign most of the counties in the U.S. to recruiting offices, it cannot be assumed that the Coast Guard is actually covering the entire country. It may

be safer to assume that the Coast Guard actively recruits in only sixty-five specific locations. If the Coast Guard does not implement new policies which require recruiters to canvass more of their assigned areas, then the location of the recruiting office becomes even more significant.

The present Coast Guard recruiting office locations appear to be an ad hoc selection based on some unknown parameters and constraints. There is no documentation available to explain the locations or thought processes involved in selection. While information as to why the offices are located where they are is not available, it can still be noted that location is very important and relocation may be necessary to optimize recruiting effort and expenditure. Assuming that most of the enlistees come from the immediate counties of a recruiting office's territory, the offices should be placed in locations with large numbers of highly qualified youths that have a propensity to enlist in the military. While these three factors, good quality, large number of youths, and propensity to enlist, are not all inclusive in determining a good location, they are a good starting point for evaluation.

In summary, the Coast Guard realizes that it must improve its recruiting process to maintain a population of high quality individuals in a high quality service. Due to the limited resources for Coast Guard recruiting and the fact that Coast Guard recruiters concentrate most of their effort within a small radius of the office, the actual location of the office becomes very important. The Coast Guard Enlisted Recruiting Branch has expressed some concern over the present locations of Coast Guard recruiting offices. Some cities without Coast Guard recruiting offices seem to have a lot of potential and produce well for the other services, while other cities with Coast Guard offices are unlikely choices. For example, the Coast Guard has three

offices with a total of eleven recruiters in the state of North Carolina, while there are only three offices and ten recruiters in all of Southern California. Based on population and the amount of Coast Guard activity in these two locations, there appears to be some discrepancy in recruiter location. Discrepancies such as this indicate that the present location of recruiting offices may not be 'optimal'. Relocation of the recruiting offices is a step towards improved recruiting. If the offices can be located in areas that have a large number of high quality youths with a propensity to enlist in the service then the Coast Guard should be able to improve the quality of enlistees with less effort.

II. RECRUITING OFFICE LOCATION MODELS

A. THE ARMY, AIR FORCE, AND NAVY MODELS

Most of the academic literature on recruiting has concentrated on the influence of the civilian-military pay ratio and the civilian unemployment rate. Although these two factors are obviously significant in forecasting enlistments into the military, they are not all-inclusive. As a result of recent studies and advancements in knowledge of military recruiting, the models used by the major services to predict enlistments have become much more sophisticated. Many possible variables that influence recruiting have been identified and tested. Extensive research has resulted in similar supply models for each of the services.

The major services have divided potential recruits into two classes, "supply limited," and "demand limited." The supply limited class consists of mental category I-IIIA high school graduates without prior military service. These people rank in the upper 50th percentile on the ASVAB Test (Armed Services Vocational Aptitude Battery), have graduated from high school, and do not have any previous military service. This group is considered supply limited because the number of accessions into the military from this group of people is limited by the supply available and not the military's demand. In essence, this group of individuals has been identified as desirable for military enlistments. The "demand" class of people consists of the mental category IIIB and below (lower 50th percentile on the ASVAB Test) or non- high school graduates and GEDs (graduate equivalency diploma), with prior and non prior service personnel combined. This group appears to be constrained by the limit that each of the services will allow.

Since the supply limited recruit is the goal, each of the services has developed an enlistment supply model that relies on the assumption that the category I-IIIA nonprior service high school graduate is a limited resource for enlistment into the military. This supply model is used in making decisions about recruiter allocation, budgeting, advertising, etc.. To describe the enlistment supply model the Cobb-Douglas function is used [Ref. 5, and 6] with the general form as follows:

$$Y = e^{ac} X_1^{a1} X_2^{a2} \dots X_n^{an} \tag{2.1}$$

where Y represents the supply limited accessions or dependent variable, Xi's are the independent variables representing the recruiting and environmental factors, and the ai's are the exponents of e and the independent variables. The Cobb-Douglas function is intuitively appropriate in recruiting because of the property of diminishing returns.

The environmental and recruiting factors, or independent variables, vary with each service. Some of the major factors found in these models are number of recruiters or effort, qualified military available (17-21 year olds), unemployment levels, youth attitude towards the military, advertising, recruiter experience, office workload, and previous accessions [Ref. 5, 7, and 8]. While these factors are not exhaustive, they represent the major ones which are incorporated into the models. When building these models it is necessary to avoid using too many factors to describe the supply function. As Beswick [Ref. 7] points out there are two possible problems with each factor. First, an appropriate measure for each variable must be made. In many cases the appropriate measure is not obvious. For example, it is not obvious what the appropriate measure is for the youth attitude towards the military. A second problem

involves which variables to include in the model and identifying the functional interaction between the variables chosen. It is for these reasons that a minimal number of explanatory variables should be used to describe the supply response.

B. THE COAST GUARD RELATIVE TO THE OTHER SERVICES

As discussed above, the other services use their models to assist in making recruiting decisions about recruiter allocation, budgeting, advertising, number of recruiters, assignment of recruiting goals, forecasting enlistments, performance evaluation, and office locations and boundaries. The Coast Guard is also faced with recruiting decisions. However, the recruiting branch does not have a Coast Guard supply model to assist in these decisions. Because of major differences such as size, resources, and requirements, the Coast Guard cannot directly employ one of the other service's models.

The Coast Guard has very limited resources such as money, recruiters, and locations. The number of recruiting offices is a good example to contrast the Coast Guard with the other major services. The Coast Guard has sixty-five recruiting offices whereas the Navy has about 1300 and the Army and Air Force have similar numbers. The number of recruiters is also significant, but then so is the number of recruits that each service must obtain. The quantity of recruits is easily achieved in the Coast Guard as evidenced by a recent Commandant's Bulletin [Ref. 9], suspending all enlistments until 1 October (the beginning of the fiscal year). For the Coast Guard quality is the major concern. The present goal of Coast Guard recruiting is to enlist high quality white and minority high school graduates to maintain an efficient and effective service. A combination of a few

administrative policy changes and the optimal location of recruiting offices can be used to obtain this goal.

The optimal location of Coast Guard recruiting offices presents a challenging problem for a supply model. If a valid supply model for the Coast Guard can be developed, then it is possible to rate the potential of any location and subsequently make a decision to place or remove a recruiting office. As noted earlier the major services use their supply models for various recruiting decisions. Since the Coast Guard's goal is to obtain optimal location for its present sixty-five offices and 242 recruiters, the subsequent supply model will concentrate on this specific goal.

C. THE COAST GUARD REWARD MODEL FOR OPTIMAL LOCATIONS

In developing a supply model for the Coast Guard there exist several problems which must be overcome. The three major problems are the Coast Guard quota system and resulting bias of recruiting data, the restriction of available Coast Guard data to sixty-five specific locations, and the limited data available to develop a good model.

The first problem is a result of the Coast Guard's present quota policy. To determine the quota for a recruiting office, the Coast Guard starts with a forecast of the total number of recruits needed for the year. Based on expected attrition, this number is then divided into twelve monthly quotas. This figure is then divided by the total number of recruiters in the Coast Guard to yield a monthly quota for each recruiter. The quota for each office is simply the monthly quota per recruiter multiplied by the number of recruiters assigned to the office. This method assumes equal productivity among recruiters. Since quotas are usually met, this system does not seem to present a problem for quantity of recruits. However, an improved

quota assignment method may improve quality of recruits and deserves some consideration. Also, the number of recruits from each office is directly proportional to the number of recruiters assigned, hence it is not possible to evaluate the potential of an office by using number of enlistments alone.

To alleviate this problem, the Coast Guard supply model is altered to become a 'reward' model. The other services' supply models use number of enlistments as the dependent variable because this is the number that they are interested in predicting. Because of the waiting lists to join the Coast Guard, the Coast Guard is not as interested in the number of enlistments as it is in the quality of its enlistments. Because of the emphasis on quality as opposed to quantity, it is not necessary to use the number of enlistments as the dependent variable in the Coast Guard model. Using this simplifying assumption, the Coast Guard model becomes a reward function where each office is given a reward value based on the quality of its recruiting.

The reward function developed for the Coast Guard is a result of subjective weighting of five basic factors; quality enlistments, quality minority enlistments, total number of accessions that have survived at least nine months of service, total number of minority accessions that have survived at least nine months of service, and total number of applicants. The quality factor is measured by the total number of mental category I and II high school graduates with no prior service that enlisted in a given office. As mentioned before, this appears to be an accepted measure of quality and this information is readily available. The quality minority factor is the same as the quality factor except it records only the minorities in this category. The total accessions (minority and non-minority), that have survived at least nine months of service is a result of the

fiscal year 1983 accessions that were still in the Coast Guard at the time of this study. This measure represents survivors and therefore good recruits. It also buffers the bias due to the quota system, since survivors are not directly proportional to number of recruiters, hence there is a slightly lower correlation between the two. The final factor, total number of applicants, is also readily available and represents a measure similar to total enlistments for the other services. Since there is no quota on applicants, the total number is not forced to be directly proportional to the number of recruiters, hence a small office with two recruiters may have more applicants then a large office with six recruiters. The weighting of these factors was arrived at by a survey of Coast Guard recruiting experts and will be discussed further in Chapter III below.

The second problem results from having only sixty-five recruiting offices spread over the entire country. In the case of the Navy, there are approximately 1300 recruiting offices throughout the country. With this type of coverage the Navy has recruiting data for any location that it may want to consider. This allows the Navy to evaluate the potential of a given office location and then reallocate recruiters accordingly. The Coast Guard cannot use its data to evaluate the potential of a recruiting office which does not exist. For example, there is no way for the Coast Guard to use only Coast Guard recruiting data to evaluate the potential of an office in Anchorage, Alaska, since there is no office there and hence no source of Coast Guard data.

One possible solution to this problem is to develop some relationship between Coast Guard recruiting and Navy recruiting. If there is a valid relationship, then it would be possible to evaluate the potential of locations such as Anchorage using Navy data. It may be possible to develop a valid relationship based on the similarities of the two sea

going services without assuming that the characteristics of a Navy enlistee are the same as those of a Coast Guard enlistee. The psychological aspect involved in an individual's decision process for enlisting into either service is beyond the scope of this study. It is reasonable to assume that if the Navy is capable of recruiting good quality people for a given area then the Coast Guard should have some relative potential in that area also.

The final problem deals with sparse Coast Guard data. Since the Coast Guard enlists only between 4000 and 6000 recruits each year, the resulting recruiting data is very limited. For example, the number of quality minorities per office has a range of zero to five for fiscal year 1983, with most of them falling at zero, one, two, or three. As a result an increase by one or two in this category of recruit brings about a 100 to 200 percent increase in the value of this variable. This can cause difficulties when regressing against some weighted value of this variable. This sparse data is compounded by recruits that come from outlying counties of a recruiting office territory. For example, the Omaha recruiting office has a territory of about ninety counties throughout Nebraska. From these ninety counties the two counties which are in the immediate vicinity of the office produce about seventy percent of the recruits. It is reasonable to assume that most of the recruiting effort is concentrated in these two counties, hence the remaining counties are not actively recruited by the Coast Guard. In comparing the Coast Guard with the Navy, it is necessary to compare only these two counties since they are the only two that the Coast Guard makes an effort to recruit from. If all ninety counties were compared then the results would be misleading because the Navy has offices and actively recruits in some of these counties that the Coast Guard cannot cover. In the case of Omaha, there is a loss of

about thirty percent of the data by using only the two counties for comparison to the Navy. This loss summed up over all locations results in a much smaller amount of useful data. The overall effect is that the useful Coast Guard data is very limited and the relationship that is developed through regression with Navy recruiting data should be treated with caution.

Keeping in mind the three major problems as mentioned above, Coast Guard quota system, limited number of locations, and limited amount of useful data, a Coast Guard 'reward' model can be developed. The model is a multiplicative model with the dependent variable defined as the reward assigned to each office and the independent variables are the relevant Navy variables, and number of Coast Guard recruiters. The Coast Guard quota system and interest in quality justifies the use of a reward value for each office. For example, the Coast Guard would prefer an office that produces many category I and II, and minority category I and II accessions with only a few recruiters, over an office that requires many recruiters to produce only a few category I and II, and minority category I and II accessions. It is reasonable then, to evaluate each office based on some reward level as a function of the quality of accessions obtained.

The limited number of Coast Guard locations results in using the Navy data as the most convenient set of independent variables. This Navy data is readily available and is logically relevant to the problem at hand. It is reasonable to assume that there is a correlation between Navy and Coast Guard recruiting results. Using the reward value to regress against the Navy data results in the following model:

$$\text{Reward} = f(\text{Navy data, \# of C.G. Recruiters}) \qquad (2.2)$$

It is this reward model which will subsequently be used as the driving force in determining the optimal location. The final problem of the limited amount of useful Coast Guard data suggests that any decisions based on this model must be treated with caution.

D. OPTIMAL LOCATIONS VIA THE REWARD MODEL

To determine the optimal location of recruiting offices for the Coast Guard there must exist a valid reward model. Assume this model is of the form

$$R = f(X_1, X_2, \ldots, X_n, d) \tag{2.3}$$

where the X's are the various explanatory variables mentioned earlier and d is the decision variable, number of recruiters. Then it is possible to use this function as a recruiting decision aid. The first step in applying this model is to define the problem in terms of the model. Since the Coast Guard wants to optimize their recruiting office locations the logical step is to optimize the reward function of all the Coast Guard recruiting offices as follows:

$$\text{Max} \sum_{i=1}^{N} R_i \tag{2.4}$$

where Ri is the reward for office i and N is the total number of recruiting offices under consideration. To complete the problem there must be some constraints added to the system or the solution might result in a office at every location considered.

The constraint for the Coast Guard's problem is the total number of recruiters available in the Coast Guard. This number is 242 at the present time with an additional constraint that there must be at least two and not more than six recruiters in any office. This second constraint is a

result of administrative requirements. The resulting problem may be described as follows:

$$\text{Max} \quad \sum_{i=1}^{N} R_i \qquad (2.5)$$

$$\text{s.t.} \quad \sum_{i=1}^{N} d_i = 242$$

$$2 \leq d_i \leq 6 \qquad \text{for all } i.$$

where di is the number of Coast Guard recruiters for office i. Given this formulation, the question remains of how to solve it.

The method used for the Coast Guard problem involves applying a dynamic programming technique similar to the one used by Beswick [Ref. 10] in an application for Air Force recruiting. In the Air Force problem, Beswick proposes a "response function" as follows:

$$r_i = z_i \, t_i^a + C_i \qquad (2.6)$$

where

r = number of reservations in office i,

z = all of the explanatory variables for office i with the exception of recruiting effort,

t = man-months of effort in office i, and

C = a constant.

This multivariate response function was derived using a non-linear regression method. Beswick then applied a dynamic programming algorithm with t , man-months of effort in each office i, as the decision variable to solve the problem given by equation 2.7 , where T is the total number of Air Force Recruiters.

$$\text{Max} \sum_{i=1}^{n} r_i \tag{2.7}$$

$$\text{s.t} \sum_{i=1}^{n} t_i = 12T$$

A comparison of equations 2.5 and 2.7 shows two very similar problems. To apply the dynamic programming method to the Coast Guard problem there are a few adjustments to be made. First the reward model must be a function of Coast Guard recruiting effort (i.e. Coast Guard recruiting effort must be one of the explanatory variables). As a result the reward model may be written as follows:

$$R_i = Z_i \, d_i^a \tag{2.8}$$

where

R_i = the reward at office i,

Z_i = a value determined by the Navy explanatory variables for office i,

d_i = the number of Coast Guard recruiters for office i, and

a = the exponent for d_i derived from the regression.

Because of the relatively small number of Coast Guard Recruiters, the variable d was chosen as the number of recruiters for an office instead of the man-month effort or some other percentage of recruiting effort. Since d is the decision variable and must be an integer, the resulting dynamic programming algorithm must result in an integer solution. The added constraint of at least two and not more than six recruiters per office is also incorporated in the dynamic programming solution.

Assuming a valid reward model, the application of the dynamic programming algorithm should produce a list of

offices with the corresponding number of recruiters that will maximize the total reward for the Coast Guard.

III. MODEL ESTIMATION

A. IDEAL CONDITIONS

To develop a good reward function it is necessary to define and understand the model. As mentioned before, a multiplicative factor model will be used to describe the reward function for Coast Guard recruiting. This type of model is intuitively convenient since it allows the case of diminishing returns of reward as a function of effort. Several studies on market response to sales force have concluded that there are diminishing returns as a function of effort as shown in Figure 3.1 [Ref. 11, 12, and 13].

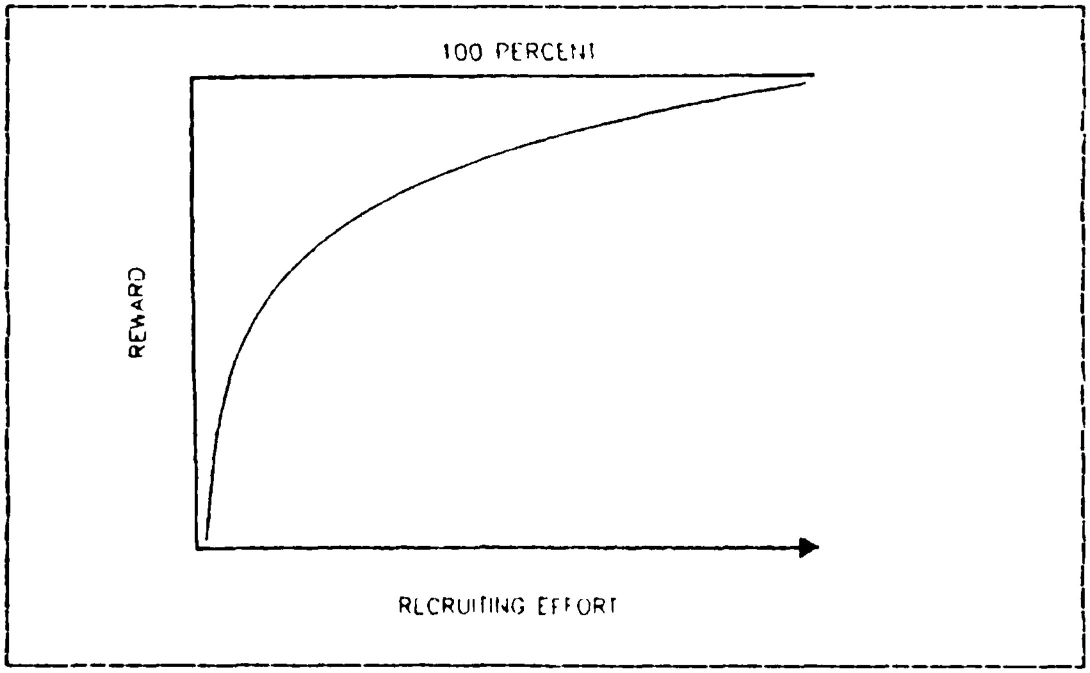

Figure 3.1 Reward as a Function of Effort.

Assuming that this multiplicative factor model is appropriate, the first step to building the model is identifying all possible components. It is hypothesized that the reward function is affected by both environmental-demographic conditions and recruiting system factors. The first set of conditions, environmental-demographic, are not directly controllable by the Coast Guard; however, recruiting office location can be adjusted to optimize these conditions. The second set of factors, those of the recruiting system, is more directly controlled by the Coast Guard within the limits of budget constraints and Congressional rulings, and therefore should be heavily scrutinized to insure effective recruiting.

The Coast Guard recruits heavily from the age group of 17-21 years old, hence the relative number of youths in this category should have a positive influence on recruiting. This group is commonly referred to as the "qualified military available" (QMA), the youths in the age group of 17-21, that are physically and mentally qualified, and available for military service [Ref. 5]. This factor, QMA, is considered an important factor in the supply models of all the other services and provides a good starting point in identifying geographic areas with good potential [Ref. 5].

Another important environmental factor is the local unemployment rate. Several studies indicate that high unemployment has a positive effect on recruiting [Ref. 5, 8, and 14]. This is intuitively reasonable since people will turn towards a secure income, the military, during hard economic times. This effect was quite evident during 1982 when the unemployment rate was high throughout the country and recruiting was good for both quality and quantity for all of the services.

The civilian-military pay ratio is another economic factor which influences recruiting. When this ratio is

high, meaning higher civilian pay relative to the military, the effect on recruiting is negative. Although this relationship is expected, the possible interaction with unemployment must be considered if both factors are included as explanatory variables in the model.

Youth attitude toward the military is another environmental factor which cannot be controlled. Recent surveys indicate that the popularity of the military is on an upswing from a very low level reached during the Vietnam era [Ref. 15]. While popularity has a positive effect on recruiting, as would be expected, this popularity is not consistent across the country. Different regions seem to experience different levels of popularity. The annual Youth Attitude Tracking Study (YATS), divides the country into sixty-six regions with a rating for propensity to enlist into the military. While some of the services include this as an explanatory variable for their supply models, the Coast Guard will not include it because the rating is based on a survey of propensity to enlist in one of the other services. The survey excludes the propensity to enlist in the Coast Guard, and it is not clear how this measurement of attitude towards the military would fit into the Coast Guard reward model.

Possible recruiting system factors which affect recruiting include: office workload, advertising, the programs offered, recruiter experience, and number of recruiters, just to name a few. For the Coast Guard reward model, the number of recruiters assigned to a geographical area will be the only explanatory variable from the recruiting system factors. This factor, number of recruiters, is considered one of the most important variables related to recruiting and is the easiest to quantify for each geographic location. The other recruiting system variables are hard to define and even harder to measure. For

the purpose of this study, the number of recruiters assigned to a location will be synonymous with recruiting effort for that location.

In a study done for the U.S. Army by General Research Corporation [Ref. 5], the explanatory variables for their cross sectional supply model included QMA, unemployment, attitude towards the military, advertising, number of recruiters, and number of canvassers. This represents one set of explanatory variables which were considered appropriate for the prediction of Army enlistments. These variables would be nice to consider in the Coast Guard model, however the construction of the reward model, the availability of the data, and the ultimate use of the model, dictates that the Coast Guard Reward Model use a different set of explanatory variables.

B. DATA AVAILABLE

Since the goal of the reward model is to predict the recruiting reward for geographic locations both with and without Coast Guard recruiting offices, it is hypothesized that the performances of Navy recruiting efforts can be used to predict the performance of Coast Guard efforts. If this hypothesis is true, then it will be possible to predict the reward of geographic locations for present and potential Coast Guard recruiting offices. Using Navy data to predict Coast Guard potential allows the prediction in areas where there is no source of Coast Guard data and also overcomes the problems caused by a lack of detailed Coast Guard data. Even for the locations where the Coast Guard has recruiting offices there is a lack of good differentiable data beyond that of total enlistments (i.e. there is no division into mental categories or minority mental categories, etc.).

The data used for this study were obtained from the Defense Manpower Data Center (DMDC). The DMDC provided both Coast Guard and Navy data for fiscal year 1983. The data included information such as; home of record FIPS (Federal Information Processing Series) code, highest year of education, race, AFQT score, service of accession, and Coast Guard recruiting office, for each applicant of both services, Coast Guard and Navy. These data were then manipulated into number of applicants, mean AFQT of applicants, mean AFQT of accessions, number of accessions, number of category I and II accessions, number of category I and II applicants, number of minority category I and II accessions, number of minority category I and II applicants, the number of minority accessions, and the number of minority applicants for both of the services. This list of variables of Coast Guard data would become the possible components of the reward value for each location, while the Navy data variables along with the number of Coast Guard recruiters at each office would become the explanatory variables. In the case of Coast Guard accessions, the number registered for each office represents those enlistees that survived at least nine months of Coast Guard service. This was a hidden bonus since the number of accessions represents survivors and, hence, is an aspect that should be rewarded.

Initial review of the Coast Guard data for the various categories suggested that some of the data values were suspect. A closer comparison of numbers that are maintained by the Coast Guard Headquarters Enlisted Recruiting Branch revealed that many of the values obtained for the sixty-five locations are in error. Elimination of the invalid data points resulted in thirty-four locations on which future calculations and estimations would be based. There was no reasonable explanation for the inconsistent data results; however, it is hypothesized that the Coast Guard's reporting

procedure to the DMDC may have resulted in some offices not receiving full credit for their recruiting efforts. The loss of almost half of the original data suggests that caution should be used when drawing conclusions from any subsequent results. It is also possible that the remaining data may have errors that could not be checked due to the lack of detailed data maintained by the Coast Guard.

After the invalid data were eliminated from the data set, the first step involved exploratory data analysis. A scatter plot of each variable mentioned above was made against each of the other remaining variables for both Coast Guard and Navy data. In addition the correlation coefficient was recorded for each comparison. This made it possible to get a better overall understanding of the data and to identify outliers and relationships within the data. Obvious relationships such as Navy applications versus Navy accessions appeared as nearly straight lines, suggesting that a strong relationship between these variables exists. The resulting correlation coefficient of .94 supports this conclusion. It is necessary to be aware of these possible interactions since it is not desirable to include two explanatory variables that are strongly interrelated.

This exploratory data analysis was also useful in identifying the most desirable variables to include in the model for further analysis. The independent variables that appeared to be significant were number of Coast Guard recruiters, Navy accessions, Navy category I and II accessions, and Navy minority category I and II accessions. The overall view of the data also proved helpful when analyzing the subsequent regression results. A final result of the exploratory data analysis was the confirmation of the fact that the Coast Guard data was noisy.

C. THE VARIABLES USED IN THE REWARD MODEL

Although there are some limitations on the variables considered for the reward model due to a lack of data, there still exists a substantial set of possible variables to represent both the dependent and independent variables of the model. The dependent variable in this model represents the reward assigned to each office. This reward will be discussed in detail in the next section following a closer look at the five variables that make up this single reward. These five variables include applications, accessions, category I and II accessions, minority category I and II accessions, and minority accessions, all with respect to the Coast Guard.

The first variable, applications for the Coast Guard, is measured by those individuals that pursued the application process to at least the level of taking the ASVAB test. This eliminates the people who simply fill out a form or two without any real interest in making a commitment. It is hypothesized that an individual who sacrifices the time to fill out the applications and take the ASVAB test is a genuine candidate for enlistment, whereas someone who merely contacts the office or picks up some brochures is not necessarily a serious candidate. The number of these applications is not limited by any quota system and is not directly proportional to the number of recruiters, hence an office that gets many serious applicants may represent a location with very good potential. It will be assumed that the potential of an office is positively related to the number of applicants at that office and, therefore, an office will be rewarded with respect to the number of applications received.

The next variable to be incorporated in the reward is the number of accessions for each office. It has been

pointed out that, due to the quota system, the number of accessions for each office is directly proportional to the number of recruiters. Because of this proportionality, it is not appropriate to use the number of accessions as a dependent variable while using the number of recruiters as one of the explanatory variables. Because of this relationship, the number of accessions will be measured by those individuals who entered the Coast Guard in fiscal year 1983 and remained on active duty until the time of this study, a minimum of nine months service. This measurement was achieved by DMDC through a cross comparison of individuals on active duty at the time of this study with those individuals who enlisted in fiscal year 1983. As a result, the modified number of accessions represents individuals who have survived the period of highest attrition (through boot camp), thus representing good recruits relative to time and money involved from the signing of the enlistment contract to the time of reporting to their first duty assignment. This measurement also buffers the proportionality between number of recruiters and number of accessions which is a desired effect. Since recruits that survive at least nine months of service represent a desired commodity, a large number of these accessions implies a good recruiting location, hence each office should be rewarded with respect to the number of these accessions.

Another variable considered to be a reward is the number of minority accessions into the Coast Guard. Again these minority accessions represent those minority individuals who have survived at least nine months of service. The Coast Guard has a goal of at least twenty percent minority enlistment each year. In order to reach this goal, the Coast Guard has allocated a large number of resources in an attempt to recruit more minorities. It is more difficult to recruit minorities that meet the minimum Coast Guard

standards than it is non-minorities. For this reason it is assumed that an office that is able to recruit minorities should be rewarded accordingly; hence, a positive reward is assigned to each minority accession.

The final two reward variables are the category I and II accessions and the minority category I and II accessions. These are measured by accessions that survive nine months of service, have a AFQT score greater than sixty-four, and a high school diploma. These accessions represent quality accessions based on their mental category and education level as discussed previously. Since the ultimate goal is to improve quality while maintaining the appropriate quantity, it is assumed that the quality of recruits from each office should play a major role in the reward to that office. Again, these quality accessions are not biased by the quota system.

The explanatory, or independent, variables for the Coast Guard model are all measures of Navy performance in the various categories and the number of Coast Guard recruiters at each location. The Navy variables are the same as the five variables mentioned for the Coast Guard with the exception that they represent the values obtained by the Navy in each location. The number of Coast Guard recruiters is important since the recruiting results are a function of effort. Since the hypothesis is to use Navy performance to predict Coast Guard potential it is reasonable to use similar measures of Navy performance to predict Coast Guard potential. If there is a positive relationship between Navy and Coast Guard recruiting, then the Coast Guard should be willing to allocate resources in locations where the Navy does well and compete for the relatively few accessions that are required.

The explanatory variables mentioned above represent a starting point for the model. The process of stepwise

regression will eliminate those variables that are not truly explanatory and will keep those that are. It is necessary to begin with variables that have some apriori justification for being in the model to avoid predicting within a given significance level using some unrelated variable.

D. REWARD ASSIGNMENT

As previously mentioned, this study is using a "reward model" instead of a "supply model" because the ultimate goal is quality not quantity. This reward theory is also a convenient buffer for the quantity bias created by the Coast Guard quota system. To develop a reward value for each of the offices with data, it was necessary to survey some recruiting experts to determine which categories were the greatest assets to the Coast Guard. Once the categories were ranked from most important to least important, a subjective weighting was given to each variable to differentiate the levels of significance. It is assumed that these recruiting experts are making the decisions for the Coast Guard recruiting system, including those regarding the quality of recruits. Hence, their subjective ranking and weighting of the reward values should be consistent with the quality goals of the Coast Guard.

The reward (dependent variable) assigned to each office is defined by the following equation:

$$R = APP + 2(ACC) + 4(CATAC) + 4(MCATAC) + 3(MINAC) \quad (3.1)$$

where APP = number of Coast Guard applications,

ACC = number of Coast Guard accessions,

CATAC = number of Coast Guard category I and II accessions,

MCATAC = number of Coast Guard minority category I and II accessions, and

MINAC = number of Coast Guard minority accessions.

It should be noted that each category is mutually exclusive of the others (i.e. APP represents applications above and beyond the other four categories). The weighting of these rewards is intuitively reasonable since the highest rated reward is quality. Both minority and non-minority quality are weighted on an equal basis. This suggests that improved quality is more important than increased minority accessions, since minority accessions are rated second highest. This is followed by regular accessions because the minority recruit is more difficult to obtain than the non-minority, hence a higher reward should be given. The final variable is applications. This variable is appropriate to include because it represents a potential recruit. These applicants pursued the enlistment process to a level indicating sincere interest. Poor recruiter performance or a long waiting list are possible reasons for an applicant not enlisting in the Coast Guard. This suggest that applicants are valid indicators of potential recruits.

E. INITIAL REGRESSION USING STATISTICAL ANALYSIS SYSTEM

Once the list of independent variables was identified and the dependent variable (reward) was defined, the actual estimation of the parameters and the determination of the independent variables which would remain in the model was conducted. The statistical technique chosen was a stepwise regression package available through the Statistical Analysis System (SAS). A review of the reward model

$$R_i = e^{a0} X_{1i}^{a1} X_{2i}^{a2} \dots X_{ni}^{an} d_i^{a} \qquad (3.2)$$

reveals that a logarithmic transformation must be completed before estimating the parameters using a linear stepwise regression. The transformation results in the following equation:

$$\ln(R_i) = a0 + a1 \ln(X_{1i}) + a2 \ln(X_{2i}) + \ldots + an \ln(X_{ni}) + a \ln(d_i) \quad (3.3)$$

where Ri = the weighted reward value for office i, and

$$\left.\begin{array}{l} X1i \\ X2i \\ \\ Xni \\ di \end{array}\right\} = \text{the explanatory (independent) variables.}$$

Once this transformation is made, it is possible to apply linear stepwise regression to estimate the parameters; ao,a1,a2,...,an,a. Several regressions were conducted on the data with various combinations of independent variables and various weighting of the dependent variable to measure the sensitivity of the model under varying conditions. In addition, the level of significance for the independent variable entry into the model was varied to ensure that all possible factors would have a chance to be considered.

F. REGRESSION RESULTS

The stepwise regression for the thirty-four locations resulted in the following equation:

$$\ln(R_i) = 4.41 + .12 \ln(NACC_i) + .49 \ln(d_i) \quad (3.4)$$

where NACC = number of Navy accessions at location i, and

di = number of Coast Guard recruiters in location i.

Taking the inverse log of Equation 3.4 results in the following multiplicative model.

$$R_i = 82.3\ NACC_i^{.12}\ d_i^{.49} \quad (3.5)$$

As can be seen in Equation 3.5, the prediction model is defined with only two explanatory variables. The presence of the 'di' variable is expected, because it is assumed to

be the most important factor influencing recruiting, and it is this 'di' variable which will subsequently determine the allocation of recruiters. The NACC variable implies that the Coast Guard reward has some positive relationship with the total number of Navy accessions. The elasticity of this variable is represented by the .12 exponent. Since the NACC variable is not highly correlated with any one of the dependent variables it is reasonable to include it in the model. To expound any further upon these variables seems inappropriate when considering the possible invalid data. It suffices to note that each of the explanatory variables had an apriori justification.

Closer investigation of the regression results shows an R^2 of about .63. This is considered a fair value when dealing with quantitative social data. However, caution must be used when making conclusions based on a large R^2, because the independent variables may make only a statistical explanation and not the desired causal explanation [Ref. 16].

The F probabilities for d and NACC were .0001 and .0058 respectively. These values imply that there is only a .01 percent probability that the d appears as an explanatory variable by chance and likewise a .58 percent probability for NACC. These are both very good significance levels and suggest that both variables have been appropriately selected as explanatory variables.

The variable that the model attempts to predict, reward, was arrived at subjectively, hence to construct a very complicated model with several explanatory variables could not be justified as any better than the model above. The results do suggest a relationship between Coast Guard potential and Navy performance, which deserves further investigation. It seems that a better model could be obtained if the Coast Guard could provide the necessary accurate data. The

remaining steps in determining the optimal Coast Guard recruiting locations will be carried out under the assumption that the above model is valid.

IV. DETERMINING OPTIMAL LOCATION WITH DYNAMIC PROGRAMMING

A. PROBLEM STATEMENT

Since this study attempts to determine the optimal locations for recruiting offices, the problem will be defined in terms of the goals and constraints placed upon the Coast Guard Recruiting Branch. The present budget constraints for Coast Guard recruiting allows for 242 recruiters and sixty-five offices, and the money for these resources is assumed to be available in the following years. It is also assumed that the fixed cost of an office is the same for all locations. Hence, for each office closed, a new one will be opened so as to maintain sixty-five locations. For administrative purposes, the Coast Guard desires to have a minimum of two and not more than six recruiters per office. This is to facilitate leave, continuity during transfers, keeping the office open while one recruiter is on the road, etc. If the objective function of the problem is defined by maximizing the reward at each office, where the reward is predicted by the reward model, then the problem can be formulated as follows:

$$\text{Max} \sum_{i=1}^{N} R_i(d_i) \tag{4.1}$$

$$\text{s.t.} \sum_{i=1}^{N} d_i = 242$$

$$2 \leq d_i \leq 6 \qquad \text{for all } i,$$

$$N = 65, \text{ and}$$

$$d_i = \text{an integer.}$$

For the purpose of this study, the Coast Guard Recruiting Branch supplied a list of eleven potential locations to possibly replace present offices with the least desirable reward. These locations were picked based on several logical characteristics including Coast Guard visibility, population, relative location to existing Coast Guard facilities, etc. This study looked at the seventy-six locations, sixty-five existing and eleven potential sites, eliminated the eleven locations with the lowest predicted rewards, and determined the recruiter allocation necessary to optimize the reward of the remaining sixty-five locations.

B. THE APPLICATION OF DYNAMIC PROGRAMMING

The mathematical programming problem proposed in Equation 4.1 is depicted as a dynamic programming problem in Figure 4.1 .

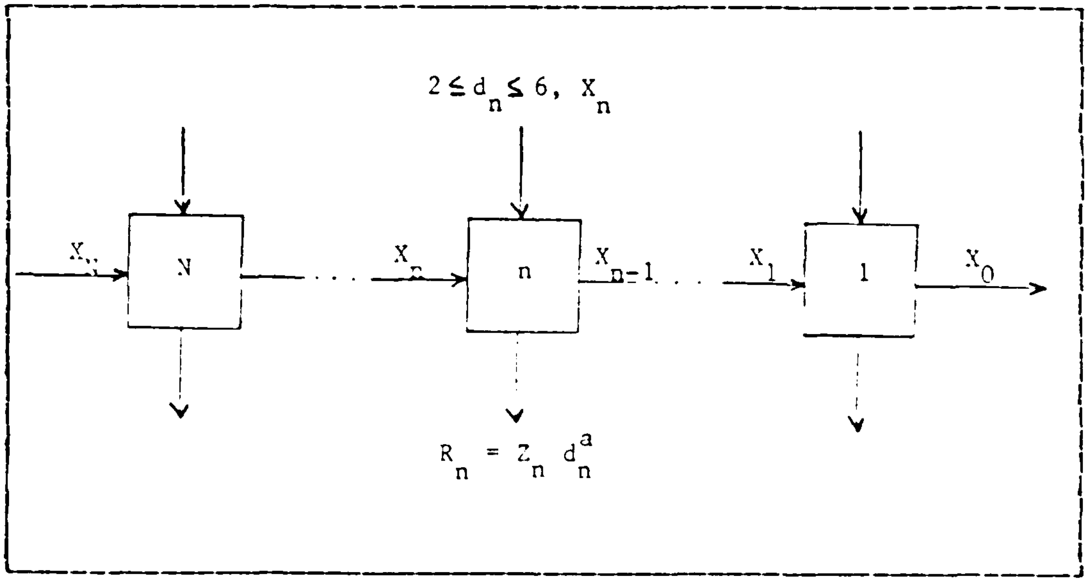

Figure 4.1 Dynamic Programming Formulation.

where di = the integer decision variable, number of recruiters at office i,

Xi = the total number of recruiters available at stage i, the dynamic programming state variable,

N = total number of stages (65), each stage represents a recruiting office,

Ri = the reward for office i.

As discussed earlier, Ri is the reward function developed in Chapter III, where:

$$R_i = Z_i \, d_i^{.49} \qquad (4.2)$$

Each Zi is a predetermined value from Equation 3.5 . This value differs among recruiting offices but is constant with respect to a given office.

The recursive equation for solving this problem is

$$f_i(X_i) = \text{Max} \; (R_i + f_{i-1}(X_{i-1})) \qquad i = 1, 2, \ldots, N, \qquad (4.3)$$

where $0 \leq d_i \leq 6, X_i$,

$X_{i-1} = X_i - d_i \qquad i = 1, 2, \ldots, N,$ and

$f_0 = 0.$

It may be noted that the constraint of maintaining exactly sixty-five offices is not accommodated in this model. One possible solution to meet this constraint is to add another decision variable to the dynamic programming formulation. This decision variable, in addition to the decision, 'di', number of recruiters at office i, would be an indicator type variable, where the value one would represent the decision to have an office at the given stage location and a zero would be the decision not to have an office. This indicator variable would be constrained such that the sum of the indicators would equal sixty-five. While the

addition of a decision variable and corresponding state variable is feasible, it is undesirable because of the resulting increase in dimensionality of the dynamic programming problem. The number of computations rises exponentially with each state variable, hence the problem can become prohibitive as variables are added. In the small problem attempted in this study, the size can be handled with the added variables, however it is not necessary if the simplicity of the reward function is exploited to account for the 'number of offices' constraint.

Review of Equation 4.2 shows that the reward function for each office is a convex function. Each of the seventy-six locations considered has a unique Zi value, a constant for that office. It can be shown that the eleven locations with the smallest Zi value can be eliminated from the problem and the resulting solution obtained from the remaining sixty-five locations and the single decision, single state variable model, will have the same optimal solution obtained from the dynamic programming problem with the additional decision and state variables. This can be proved by showing that an office eliminated from the solution of one recruiter per office (i.e. sixty-five recruiters available), will not return to the solution as more recruiters (resources) are added, while maintaining the limit of sixty-five offices. This may be stated in the following way.

If the total number of recruiters available for allocation is sixty-five and only one recruiter may be assigned to an office, then the sixty-five offices chosen to optimize the total reward will be the same offices that optimize the problem for 242 recruiters and a limit of sixty-five offices. To see this let R1(k), R2(k), ..., R76(k) be the reward values for each office if k recruiters are assigned to the offices. Let S be the set of offices eliminated from

the problem with a resource of 65 recruiters, where one recruiter is allocated to each of sixty-five offices out of seventy-six total offices. Then S is the set of offices with the eleven lowest Zi values. To confirm this it is necessary to note that if $Ri(1) < Rj(1)$, then $Ri(k) < Rj(k)$ for all k. If this were not so, then the optimal solution with a constraint of 242 recruiters and 65 offices could include an office in set S. That is: $Ri(k) > Rj(k)$ where i represents an office eliminated in the 65 recruiter, 65 offices problem, and j is an office included in this 'one recruiter per office' case. But this is not possible because: $Ri = Zi * di^{.49}$ and if $Zi*1^{.49} < Zj*1^{.49}$ then $Zi*k^{.49} < Zj*k^{.49}$ must be true. Hence, the additional state variable and decision variable can be avoided by eliminating the eleven lowest Zi offices and solving the subsequent dynamic programming problem using the remaining sixty-five locations. The final step determines the optimal allocation of recruiters for the best sixty-five offices. The resulting problem fits the description in Figure 4.1, and can be solved using only one state and decision variable, the number of recruiters.

C. NON-INTEGER SOLUTION

Before discussing the dynamic programming technique used for solving this problem, it is worthwhile looking at a non-integer dynamic programming algorithm which results from the convex nature of the objective function in this problem. While the optimal solution of this technique does not provide integer results, it does provide valuable insight into the process, gives an approximate estimate as a decision aid, and is very simple and easy to implement using existing Coast Guard resources.

Assuming that the Zi is greater than zero for all i, it can be shown [Ref. 17], that the following recursive equations represent the optimal allocation decision for each stage.

$$d_i = Q_i X_i \tag{4.4}$$

$$f_i(X_i) = K_i X_i^a \tag{4.5}$$

where,

$$Q_i = \frac{(Z_i / K_{i-1})^{1/(1-a)}}{1 + (Z_i / K_{i-1})^{1/(1-a)}}, \quad i = 2,3,\ldots,N; \quad Q_1 = 1. \tag{4.6}$$

$$K_i = Z_i Q_i^a + K_{i-1} (1-Q_i)^a, \quad i = 2,3,\ldots,N; \quad K_1 = Z_1. \tag{4.7}$$

These simple recursive equations can be programmed on the Coast Guard's C3 computer to provide a readily available decision aid for future use by the Coast Guard Recruiting Branch. Although the above algorithm will not provide an integer solution, it may be a valuable tool sufficient for Coast Guard requirements and budget constraints. Assuming that any reward or supply model developed from quantitative social data will only provide an approximate decision aid, the non-integer solution may be a more reasonable approach, based on its simplicity. Once this program is implemented, it can be adapted for annual redistribution of recruiters at already established offices, assigning quotas to offices, evaluating recruiter performance, and several other optimization schemes which may be of interest. These applications are valid assuming a valid reward function can be derived.

Although this method does not give an integer solution, the program was written and tested (without the constraints on d) for the problem described in this paper. The optimal

solution obtained was not the same as the integer solution for obvious reasons, however the relative implications were consistent to those obtained in the integer solution. As a decision aid, the non-integer solution appears to be helpful and may be sufficient for Coast Guard requirements.

D. THE INTEGER SOLUTION USING DYNAMIC PROGRAMMING

The first step, before applying dynamic programming, was to identify the geographical locations of the eleven potential offices. These locations provided by the Coast Guard Recruiting Branch, were designated by the major city within the area and are listed in Table IV .

TABLE IV

Potential Coast Guard Recruiting Office Locations

Anchorage AK
Monterey CA
Santa Barbara CA
Orlando FL
Savannah GA
Passaic NJ
Columbus OH
Oklahoma City OK
Charleston SC
Knoxville TN
Salt Lake City UT

To determine the boundaries of the locations, the Metropolitan Statistical Areas (MSA, formerly known as Standard Metropolitan Statistical Areas or SMSA's) were used. The MSA's were defined and published by the Office of Management and Budget (OMB) in June of 1983. These geographical areas represent metropolitan areas "...consisting of a large population nucleus together with

adjacent communities and areas having a high degree of economic and social integration with that nucleus." [Ref. 18]. The OMB has specific rules to determine the qualification of an area as an MSA as follows:

1. A city of at least 50,000 population, or
2. An urbanized area of at least 50,000 with a total metropolitan population of at least 100,000.

OMB established these MSA's "...to enable all Federal statistical agencies to use common definitions when studying metropolitan characteristics." [Ref. 18]. It is assumed that the MSA represents the most logical choice for geographic boundaries for the researcher without specific location knowledge.

Once these boundaries were decided, it was possible to evaluate the Zi value for all seventy-six locations. The Zi were estimated using the reward model developed in Chapter III, Equation 3.5 and are shown in Table V . The eleven locations with the lowest Zi values were dropped from the problem. These office locations are listed in Table VI .

It is interesting to look at the offices which have been eliminated. However, to draw conclusions without further investigation of the data may result in erroneous decisions. San Francisco, for example, seems like an unlikely choice to eliminate. This may have resulted from poor data (i.e. the San Jose office receiving credit for the San Francisco office), or it may be that San Francisco is not the place to be for recruiting into the Coast Guard. Some of the other locations that have been eliminated coincide with intuition, such as Helena, Boise, Yakima, and Monterey. However, it is again necessary to investigate further, in light of the data used in this study.

The remaining sixty-five locations were used in a dynamic programming package to determine the optimal allocation of the 242 recruiters. The solution produced has integer values as desired and can be seen in Table VII .

TABLE V

Zi Values For All Locations

Location	Zi Value
Portland ME	162.3
Boston MA	189.6
Providence RI	165.4
New Bedford Ma	168.7
Manchester NH	157.4
Worcester MA	163.7
Springfield MA	164.5
Pittsburg PA	173.1
Cincinnati OH	181.3
Louisville KY	164.8
St Louis MO	182.1
Memphis TN	175.2
Minneapolis MN	168.3
Kansas City MO	172.2
Omaha NE	153.6
Denver CO	182.2
New York NY	209.7
Freeport NY	189.4
Newark NJ	202.9
Philadelphia PA	205.8
Wilkes-Barr PA	177.3
Hartford CT	191.3
Albany NY	164.3
Harrisburg PA	176.6
Norfolk VA	170.2
Salisbury MD	135.5
Richmond VA	179.0
Glen Bernie MD	178.0
Alexandria VA	142.6
Morehead City NC	170.4
Raleigh NC	153.0
Greensboro NC	166.3
Roanoke VA	146.6
Miami FL	187.9
Jacksonville FL	178.3
Tampa Bay FL	183.3
Atlanta GA	185.7
Birmingham AL	170.8
Mobile AL	180.3
New Orleans LA	175.2
Jackson MS	146.1
Houston TX	191.1
Dallas TX	180.6
San Antonio TX	183.6
Albuquerque NM	192.4
Buffalo NY	179.8
Cleveland OH	188.9
Detroit MI	201.4
Niles IL	199.1
Milwaukee WI	160.1
Phoenix AZ	183.4
San Diego CA	184.8
Encino CA	166.3
Cerritos CA	207.2
San Francisco CA	142.6
San Jose CA	168.4

Table V (cont'd.)

Zi Values For All Locations

Location	Zi Value
Sacramento CA	189.6
Helena MT	118.5
Boise ID	136.1
Spokane WA	152.4
Yakima WA	137.0
Seattle WA	171.6
Portland OR	163.7
San Juan PR	153.1
Honolulu HI	155.7
Savannah GA	136.1
Charleston SC	164.0
Salt Lake City UT	147.1
Monterey CA	138.3
Knoxville TN	154.2
Oklahoma City OK	155.7
Santa Barbara CA	165.5
Orlando FL	157.3
Columbus OH	158.2
Passaic NJ	165.4
Anchorage AK	219.0

TABLE VI

Lowest Zi Values

Existing Offices	Potential Offices
Salisbury MD	Savannah GA
Alexandria VA	Salt Lake City UT
Roanoke VA	Monterey CA
Jackson MS	
San Francisco CA	
Helena MT	
Boise ID	
Yakima WA	

The solution shown in Table VII represents the optimal allocation of 242 recruiters over the sixty-five best

TABLE VII

Optimal Allocation of Recruiters

Location	1984	Optimal	Change
Portland ME	3	3	0
Boston MA	5	4	-1
Providence RI	3	2	-1
New Bedford Ma	2	4	2
Manchester NH	3	3	0
Worcester MA	2	3	1
Springfield MA	4	4	0
Pittsburg PA	4	4	0
Cincinnati OH	4	4	0
Louisville KY	3	3	0
St Louis MO	4	4	0
Memphis TN	3	4	1
Minneapolis MN	3	3	0
Kansas City MO	3	4	1
Omaha NE	3	3	0
Denver CO	3	4	1
New York NY	5	5	0
Freeport NY	4	4	0
Newark NJ	4	5	1
Philadelphia PA	6	5	-1
Wilkes-Barr PA	3	4	1
Hartford CT	5	4	-1
Albany NY	3	3	0
Harrisburg PA	5	4	-1
Norfolk VA	6	4	-2
Salisbury MD	2	0	-2
Richmond VA	4	4	0
Glen Bernie MD	4	4	0
Alexandria VA	4	0	-4
Morehead City NC	4	4	0
Raleigh NC	2	3	1
Greensboro NC	5	3	-2
Roanoke VA	2	0	-2
Miami FL	6	4	-2
Jacksonville FL	7	3	-4
Tampa Bay FL	6	4	-2
Atlanta GA	8	4	-4
Birmingham AL	3	4	1
Mobile AL	4	4	0
New Orleans LA	5	4	-1
Jackson MS	3	0	-3
Houston TX	6	4	-2
Dallas TX	5	4	-1
San Antonio TX	5	4	-1
Albuquerque NM	2	4	2
Buffalo NY	4	4	0
Cleveland OH	5	4	-1
Detroit MI	3	5	2
Niles IL	3	5	2
Milwaukee WI	3	3	0
Phoenix AZ	3	4	1
San Diego CA	3	4	1
Encino CA	3	3	0
Cerritos CA	4	5	1
San Francisco CA	4	0	-4
San Jose CA	5	3	-2

Table VII (cont'd.)

Optimal Allocation of Recruiters

Location	1984	Optimal	Change
Sacramento CA	3	4	1
Helena MT	2	0	-2
Boise ID	2	0	-2
Spokane WA	2	3	1
Yakima WA	2	0	-2
Seattle WA	3	4	1
Portland OR	3	3	0
San Juan PR	4	3	-1
Honolulu HI	1	3	2
Savannah GA	0	0	0
Charleston SC	0	3	3
Salt Lake City UT	0	0	0
Monterey CA	0	0	0
Knoxville TN	0	3	3
Oklahoma City OK	0	3	3
Santa Barbara CA	0	3	3
Orlando FL	0	3	3
Columbus OH	0	3	3
Passaic NJ	0	3	3
Anchorage AK	0	5	5

offices. This solution is valid only if the reward model developed in Chapter III is valid. Since it has been pointed out that, due to poor data, the validity of the reward model is in question, decisions based on this solution should be made with extreme caution. Although these results may not be valid, it is useful to interpret the solution to gain further insight into the problem and to serve as a guideline for future work with better data.

The numbers in the column '1984' represent the present allocation of recruiters. A zero indicated that there is no office at this location at the present time. The values greater than zero represent the actual number of recruiters assigned to the corresponding office. The 'Optimal' column indicates the number of recruiters that should be assigned at each location to achieve the 'optimal' reward, based on the reward model developed earlier. In this case a zero

implies that there should not be an office assigned at the given location. This solution is based on the constraints discussed earlier, hence there could be significant changes in the allocation if some of the constraints were varied. For this reason, the constraints of the problem should be carefully developed to avoid constraints that are actually goals. The final column, 'Change' represents the required change from present to 'optimal' allocation.

Survey of the results shows changes of one or two recruiters in several of the offices. Since the reward model is a function of Navy accessions in a given location, the offices with the smaller 'optimal' values indicate areas where Navy recruiting was not as good relative to locations with larger 'optimal' values. If the assumption that good Navy recruiting locations imply good Coast Guard recruiting locations is true, then the shift of recruiters would be appropriate. Again, this depends on the validity of the data.

Another interesting result is that approximately 86 percent of the offices have an 'optimal' allocation of three or four. Since most of the locations are metropolitan areas, the number of Navy accessions is relatively close for these areas. When this value is raised to the .12 power to obtain the Zi estimate, the resulting figure is even closer in magnitude. Some of this resulting closeness could be avoided with more explanatory variables. The Zi value is then multiplied by the decision variable 'di' (number of recruiters), raised to the .49 power. As a result of the mathematics involved, the offices have similar allocation values with the exception of those with extremely large Zi values. The offices with four recruiters have a Zi value about 1.15 times the Zi value of offices assigned three recruiters. To move up from a four man office to a five man office, the Zi ratio is about 1.11. These ratios will

always exist with a reward function made up of a Z_i value multiplied by a single decision variable raised to some power.

A lock at the 'new' locations suggests an interesting result. Anchorage is the only office that enters with a value greater than three. The five that Anchorage receives is a result of its large Z_i value, and implies that the Navy does very well in this area. Even if the reward model is not valid, the potential of Anchorage should be investigated further.

V. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The purpose of this study was to determine the optimal location of sixty-five Coast Guard recruiting offices with 242 recruiters. Recruiting office relocation was identified as one of several methods available to improve Coast Guard recruiting quality. Quality was defined in terms of AFQT category and level of education, with 'good quality' representing those individuals in the upper sixty-five percentile on the AFQT and a high school education. It was assumed that this group of individuals was supply limited and could be predicted using a multiplicative model.

Since the Coast Guard is interested in quality and not quantity, it was assumed that each office could be rated based on the quality of recruits and the potential at each office. It was also assumed that Navy recruiting performance could be used to predict Coast Guard recruiting potential in locations where Coast Guard recruiting offices did not exist. A multiplicative 'reward model' was developed to predict a reward value for any location under consideration. A higher reward value implied more potential or a better recruiting office location. This reward model was constructed using stepwise regression on the log transformation of the dependent and independent variables. Paucity and possible errors in the Coast Guard data precluded strong conclusions about the reward model and subsequent results using the reward model. However, the method should produce a valid model if accurate data is obtained.

The solution to the problem was carried out under the assumption that the reward model was valid. A dynamic

programming technique was used to determine the best sixty-five out of seventy-six locations considered and the corresponding number of recruiters to assign to each office. A non-integer dynamic programming algorithm was introduced and was found to be very easily implemented using present Coast Guard resources. This non-integer technique is considered sufficient for Coast Guard requirements and is very adequate for use with quantitative social data. It was also shown that due to the convex nature of the reward function, elimination of the lowest eleven reward values would result in the same optimal solution as the dynamic programming technique with an additional constraint. The results obtained from the dynamic programming technique were interesting, however specific conclusions about placement of Coast Guard recruiting offices were avoided because of the poor quality of data used to build the model. This study has resulted in some general conclusions and recommendations which will be discussed in the next two sections.

B. CONCLUSIONS

The first conclusion that must be considered before implementing any changes in recruiting office location concerns the data. The detailed Coast Guard data obtained from DMDC was compared with raw numbers maintained by the Coast Guard Recruiting Branch. As a result, thirty-one of the sixty-five offices were eliminated from the regression step due to major discrepancies. Because the Coast Guard does not maintain detailed information (i.e. AFQT score and level of education) for each recruit, it was not possible to validate the specific data of the remaining thirty-four locations. Thus the Coast Guard variables used to construct the dependent variable could not be verified for errors. This leads to the conclusion that the Coast Guard data used

in this study may be inaccurate. The cause of the discrepancies have not been identified; however, the collection of accurate data should not present a difficult task for the Coast Guard. Decisions based on the data used in this study should be deferred until accurate data can be collected.

The literature that was reviewed during the course of this study strongly supports the validity of a multiplicative 'supply model'. The other services rely on this type of model to predict enlistments. The Coast Guard is interested in quality not quantity. If the Coast Guard can define and identify quality recruits then it is possible to give a quality rating to each recruiting office. The value of the rating itself is not significant, however comparison of the value with other offices can provide a technique to determine which offices have the potential for better quality. The use of a reward model to predict potential quality of an office relative to another is feasible.

Although the data used in this study was considered questionable, the resulting model does support the use of Navy performance to predict Coast Guard potential in locations where there is no Coast Guard data. This concept can be used as a decision aid if the Coast Guard is considering opening a new office in a location where there are no Coast Guard data.

Statistical Metropolitan Areas are a good set of boundaries to use for recruiting offices when specific knowledge of an area is not available. The SMA's which were defined by the OMB represent metropolitan areas with a common economic and social integration. These predetermined areas provide a good starting point until further information is available to make adjustments in the boundaries.

Once the Coast Guard is satisfied with its recruiting locations the multiplicative model can be constructed using Coast Guard data and local environmental and demographic

information. Using Coast Guard data instead of Navy data will result in a better model because there is a stronger relationship between previous Coast Guard performance and future Coast Guard potential than there is between Navy performance and Coast Guard potential. A model that uses last year's Coast Guard performance as a independent variable to predict the next year's potential is more intuitively reasonable than a model that uses Navy performance to predict Coast Guard potential.

Provided that a valid reward model can be obtained, dynamic programming is a reasonable method to aid many recruiting decisions. Some of the possible applications are recruiter allocation, quota assignment, boundary definition, recruiter performance evaluation, and recruiter time allocation with respect to specific locations within a territory. Since the basic model involves quantitative social data, the non-integer dynamic programming algorithm using recursive equations is a sufficient and reasonable approach when used with good judgement.

Most of the seventy-six locations that were considered in this study were good locations. There are some obvious exceptions such as Helena, Boise, Yakima, and Monterey. The remaining locations all have a similar potential and therefore subjective judgement could be used to reduce the number of locations to sixty-five. Once the sixty-five offices are obtained, the allocation of recruiters can be completed using the reward model and dynamic programming.

C. RECOMMENDATIONS

A reasonable method to predict Coast Guard performance has been demonstrated using a relationship between Coast Guard and Navy recruiting performance. The cost effectiveness of this method may be less than that achieved by good

judgement. If locations are carefully selected and satisfy apriori conditions, then the recruiting performance of these locations should be approximately correct. The method of 'good judgement' is more flexible in meeting political and administrative constraints. One possible approach for determining locations and the corresponding territories, is to use the Standard Metropolitan Areas. Once the locations are picked the Coast Guard can collect good data, then develop a model from this data combined with current environmental and demographic data. This model should be more accurate for recruiter allocation, quota assignment, performance evaluation, and other Coast Guard decisions, than a model that uses Navy data as an explanatory variable.

It has been assumed that the annual cost of recruiting would be the same regardless of the location of the offices if the number of offices and recruiters remain constant. As a result of this assumption, there is no cost consideration in this model. It may be necessary to develop a model that considers cost as a factor before making changes in any locations. A cost benefit comparison between recruiting office and recruiter is another model which may prove fruitful. The trade off between these two items, recruiting office and recruiter, may result in more locations with fewer total recruiters or vice versa.

Based on the results of the current study, the Coast Guard should further investigate the opening of an office in Anchorage. There is strong evidence of high quality recruiting potential in this area. The Coast Guard should also consider reallocating some recruiters as shown in Table VI of Chapter IV. One obvious imbalance is four recruiters in San Juan versus one recruiter in Honolulu.

During the course of this study there were a few ideas related to recruiting which were not directly related to the 'optimal location' problem. These ideas deserve mention

since they may help improve the present recruiting system. The first item that should be reviewed is the quota system. The present system is simple and easy to implement, however it assumes that each office has equal potential for each recruiter. This method would be reasonable if optimal allocation of recruiters has been established. Based on the origin of the present system, optimal allocation has not been achieved, hence the quota system is not reasonable. The quota system should take into account the potential of the area based on previous performance and recruiter experience. To assign quotas blindly is a disservice to both the Coast Guard and the recruiter.

Another item which can be easily improved is the lack of communication within the Coast Guard recruiting system. Under present conditions, if Honolulu has five quality applicants but only one quota for the month, four of the applicants must go on a waiting list. If at the same time San Juan has four quotas and only marginally qualified applicants, these four marginal applicants will be enlisted while four quality applicants wait in Honolulu. This problem can be easily corrected in the future when each recruiting office has a computer terminal that is connected to a central data base. However in the interim, one possible solution is to define a higher minimum standard for enlistment. If an office cannot meet quota with this new standard, then the quota will be transferred to an office with a waiting list. The Coast Guard should keep track of waiting lists to assist in future quota and recruiter allocations.

A final suggestion is to develop a recruiter incentive program. Since the recruiter is the ultimate resource to obtain quality recruits, the motivation of each recruiter is important to the overall success of the recruiting program. There are many different types of programs which have been

used by the other services and corporations throughout the world. These methods are proven and can be found in various management science publications. A well designed recruiter incentive program for the Coast Guard can result in great benefits for both the recruiters and the Coast Guard.

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